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How to rebuild a Li-Ion battery pack

Implemented for Fujitsu - Siemens Lifebook S-Series FPCBP25 battery pack
source: Electronics-Lab.com

Warning

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Did you recently notice poor performance of your notebook Li-Ion battery?. Don't be taken aback, this is happening even to the best battery! Now days Li-Ion batteries are widely used in portable devices due to there excellent energy to weight ratio and for the reason they are not suffering from "memory effect".

These two reasons make them the best choice on portable devices, but not suffering from "memory effect" doesn't mean it will last for ever! Chemical conversions inside the battery make it to produce electric energy but these chemical reactions aim to attenuate as time and charge cycles pass over.

When the battery life drops significantly it's time to search for a replacement, but you will recently find out that most of notebook batteries cost almost 1/3 to 1/2 the price of the laptop at the time you will need to replace the battery. So if you want to keep your laptop but don't want to spend much money for battery replacement it's time to think about rebuild it your own, replacing each individual cell inside the pack.

But before step on this you must consider many parameters messing around Li-Ion batteries, about the way they are charged and the way you must handle them.

Special **precautions must be taken** to avoid Li-Ion battery **fire** up or **explosion** that can cause serious injuries. This is because Lithium when comes in contact with air burns violently.

In this article we will discuss how to handle Li-Ion batteries to avoid any malfunction, the precautions you must take, the way Li-Ion batteries are charged, the protection circuits used and finally you can find a step by step guide on how to reconstruct a Fujitsu - Siemens Lifebook S-Series **FPCBP25 battery pack**. This guide can also be read as a tutorial on how to rebuild other kind of Li-Ion battery packs except the one we will use here.

It's recommended to read the following details in order to understand how a Li-Ion battery must be handled to avoid any injury, before proceed to the reconstruction of the pack.

Overview

Li-Ion (and Li-Po) batteries are leading edge battery technology and consists ideal selection in use on portable computers and cellular phones due to their high energy density and high voltage. A typical Li-Ion cell is rated at 3,6V and this is three times more than the typical NiCd or NiMH cell voltage (1,2V).

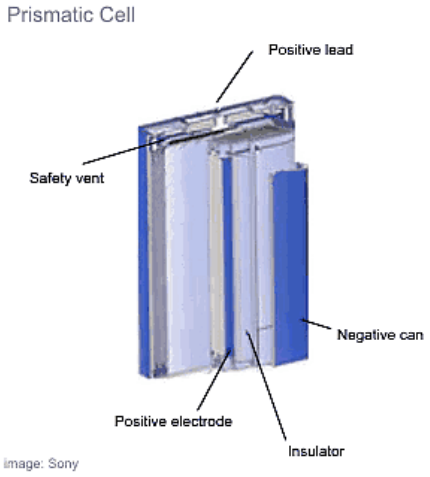
Structure

Li-Ion cell has a tree layer structure. A positive electrode plate (made with Lithium Cobalt oxide - cathode), a negative electrode plate (made with specialty carbon - anode) and a separator layer.

Inside the battery also exists a electrolyte which is a lithium salt in an organic solvent.

Li-Ion is also equipped with a variety of safety measures and protective electronics and/or fuses to prevent reverse polarity, over voltage and over heating and also have a pressure release valve and a safety vent to prevent battery from burst.

Never short circuit, reverse polarity, disassemble, damage or heat over 100 degrees Celsius a Li-Ion cell. That can be really dangerous.



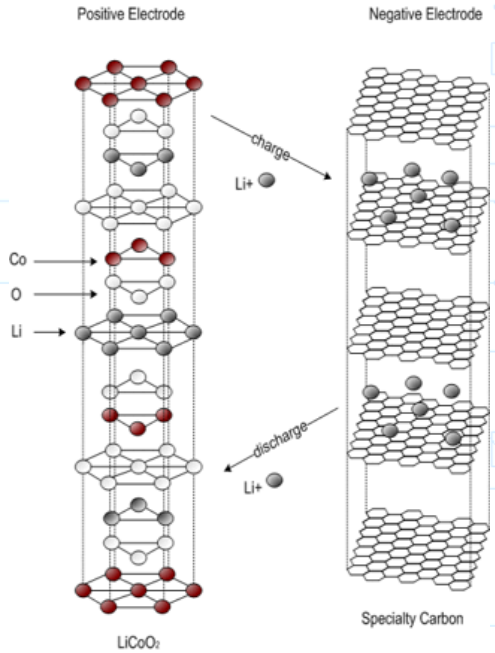
Working Principle

Lithium battery uses lithium cobalt oxide as positive electrode - cathode - and a high crystallized special carbon as negative electrode - anode.

Also an organic solvent specialized to be used with the specific carbon works like electrolytic fluid.

The chemical reaction that takes place inside the battery is as follows, during charge and discharge operation:

$$LiCoO_2 + C_6 \underset{\text{discharge}}{\overset{\text{charge}}{\rightleftharpoons}} Li_{1-x}CoO_2 + C_6L_x$$



The main principle behind the chemical reaction is one where lithium in positive electrode material is ionized during charge and moves from layer to layer in the negative electrode (as illustrated to the left image).

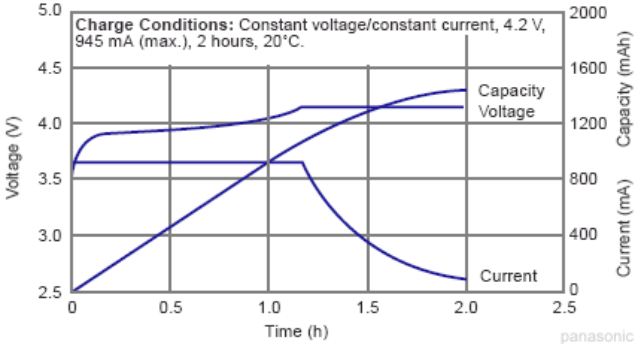
During discharge Li ions move to the positive electrode where embodies the original compound.

Features of lithium Ion batteries

- High energy density that reaches 400 Wh/L (volumetric energy density) or 160Wh/Kg (mass energy density).
- High voltage. Nominal voltage of 3,6V or even 3,7V on newer Li-Ion batteries.
- No memory effect. Can be charged any time, but they are not as durable as NiMH and NiCd batteries.
- High charge currents (0,5-1A) that lead to small charging times (around 2-4 hours).
- Flat discharge voltage allowing the device to stable power throughout the discharge period.
- Typical charging Voltage 4,2 ± 0,05V.
- Charging method: constant current - constant voltage (CV-CC).
- Typical operation voltage 2,8V to 4,2V
- Recommended temperature range 0-40°C

Charging Characteristics

Charging method is constant current - constant voltage (CV-CC). This means charging with constant current until the 4.2V are reached by the cell (or 4,2V x the number of cells connected in series) and continuing with constant voltage until the current drops to zero. The charge time depends on the charge level of the battery and varies from 2-4 hours for full charge. Also Li-Ion cannot fast charge as this will increase their temperature above limits. Charging time increases at lower temperatures.

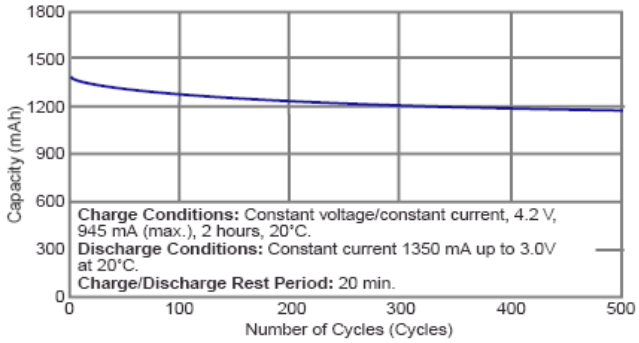


Typical charging characteristic

Charge current is recommended to be set at 0,7CmA (where C is battery capacity). If voltage is below 2,9V per cell it's recommended to charge at 0,1CmA. Charging environment must have a temperature between 0-40°C. Maximum discharge current must not exceeds 1.0CmA and discharge voltage must not go below 3,0V

Capacity

At a typical 100% charge level at 25°C, Li-ion batteries irreversibly lose approximately 20% capacity per year from the time they are manufactured, *even when unused*. (6% at 0°C, 20% at 25°C, 35% at 40°C). When stored at 40% charge level, these figures are reduced to 2%, 4%, 15% at 0°C, 25°C and 40°C respectively. Every deep discharge cycle decreases their capacity also.



Typical capacity characteristic over charge cycles

100 cycles leave the battery with about 75% to 85% of the original capacity. When used in notebook computers or cellular phones, this rate of deterioration means that after three to five years the battery will have capacities too low to be still usable.

Tip: To increase battery life store it at 40% level at low temperatures (even to the refrigerator but not below 0 degrees Celsius) and never discharge it full. Charge it early and often. Excess heat can damage the battery. Also charge once a year to prevent overdischarge.

Self discharge

One great advantage of Li-Ion batteries is their low self-discharge rate of only approximately 5% per month, compared with over 30% per month and 20% per month in nickel metal hydride batteries and nickel cadmium batteries respectively.

Chemistry Type	Ni-Cd	Ni-MH	Lead acid	Li-ion Cylindrical	Li-ion Prismatic	Li-Po
Nominal Voltage (V)	1.2	1.2	2,1	3.6	3.6 / 3.7	3.6
Specific Energy (Wh/Kg)	50	70	30	80	100-160	140
Specific Energy (Wh/L)	150	200	-	-	250-360	-
Cycle Life (Times)	500	560	-	1000	1000	-
Environmental hazard	low	medium	medium	high	high	high
Safety	High	High	medium	low	low	low
Cost	low	medium	low	high	high	high
Self-Discharge Rate (%/month)	25-30	30-35	-	6-9	6-9	-
Memory Effect	yes	yes	yes	no	no	no

Comparison table of the most common batteries types

Precautions

Be sure to follow the safety rules listed below (PANASONIC recommendations):

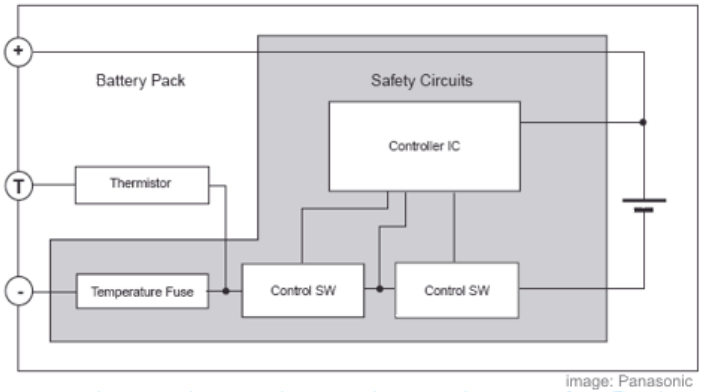
• Do not place the battery in fire or heat the battery.
• Do not install the battery backwards so that the polarity is reversed.
• Do not connect the positive terminal and the negative terminal of the battery to each other with any metal object.
• Do not carry or store the batteries together with necklaces, hairpins, or other metal objects.
• Do not pierce the battery with nails, strike the battery with a hammer, step on the battery, or otherwise subject it to strong impacts or shocks.
• Do not solder directly onto the battery.
• Do not expose the battery to water or salt water, or allow the battery to get wet.
• Do not disassemble or modify the battery. The battery contains safety and protection devices which, if damaged, may cause the battery to generate heat, rupture or ignite.
• Do not place the battery on or near fires, stoves, or other high-temperature locations. Do not place the battery in direct sunshine, or use or store the battery inside cars in hot weather. Doing so may cause the battery to generate heat, rupture, or ignite. Using the battery in this manner may also result in a loss of performance and a shortened life expectancy

Use common sense precautions. Do not short circuit, overcharge, crush, mutilate, nail penetrate, incinerate, reverse polarity, heat above 100 degrees Celsius, solder directly on the metal can. Dispose them following local batteries disposal rules.

Safety circuits inside a Li-Ion battery pack

Inside a Li-Ion pack there is always a safety circuit that consists of four main sections:

1. The controller IC that monitors each cell (or parallel cells) voltage and prevents the cells to overcharge or overdischarge controlling accordingly the cutoff switches. Also the voltage across the switches is monitors in order to prevent over current.
2. The control switches that usually comprises FET structures that cutoff the charge or discharge depending on the control signals of the controller IC.
3. The temperature fuse that cutoff the current if the control switches experience abnormal heating. This fuse is not recoverable.
4. The thermistor (usually PTC) that measure the battery temperature inside the pack. It's terminals are connected to the charger so it can sense the temperature of the pack and control the charge current until the battery it's full charged.



A typical structure of Li-Ion battery pack (block diagramm)

Battery packs made from Li-Ion cells always have protective circuits and PTC elements to monitor battery status any time. **Never** remove this circuitry as this will cause ignition.

Now you have read and understand all the above information you see that charging a Li-Ion pack can't be done with simple charge methods used in other type of batteries. So never charge a Li-Ion cell if you are not completely sure what you do.

Now it's time to continue to the step by step guide to see how we can safely reconstruct a Li-Ion pack.

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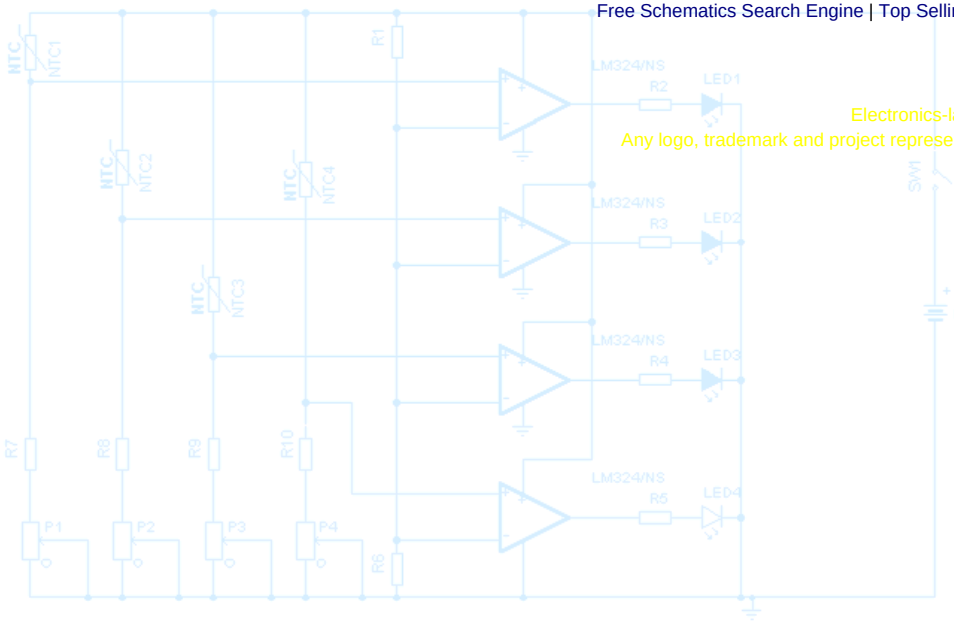

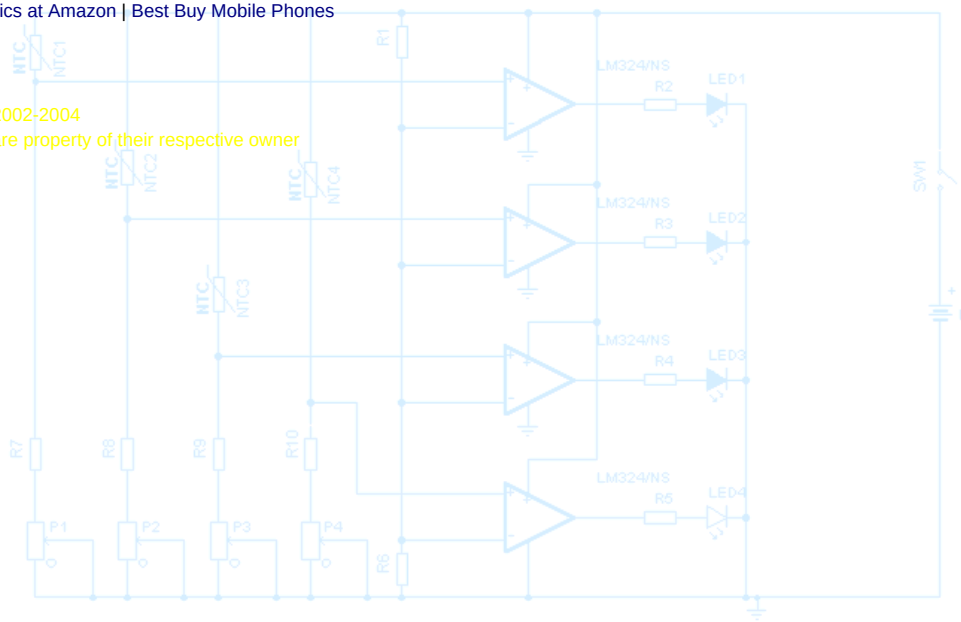

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How to rebuild a Li-Ion battery pack

Implemented for Fujitsu - Siemens Lifebook S-Series FPCBP25 battery pack
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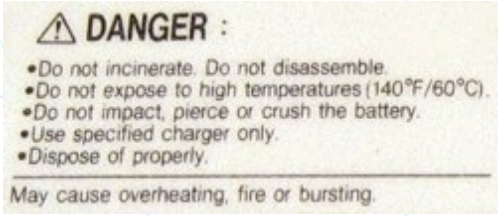
The Li-Ion battery pack we will rebuild replacing it's individual cells it's a **FPCBP25 battery pack** manufactured from Fujitsu - Siemens and used in Lifebook S-Series notebooks like Fujitsu-Siemens S4510, S4542, S4546, S4572 and S4576 ect. S-series of Fujitsu-Siemens notebooks are really nice so that's another reason you may don't like to replace your notebook with a new one. You may also find this pack listed with the number FMVNBP104 or CP024486-01. The nominal voltage is 10,8V and capacity is 2600mAh

The battery pack looks like in the above photo. You can read on the label the product number and the type of the battery (Li-Ion). You must also read all warnings listed and be sure to follow them, expect the disassemble one that we can't do it in another way:


⚠ DANGER :
•Do not incinerate. Do not disassemble.
•Do not expose to high temperatures (140°F/60°C).
•Do not impact, pierce or crush the battery.
•Use specified charger only.
•Dispose of properly.
May cause overheating, fire or bursting.

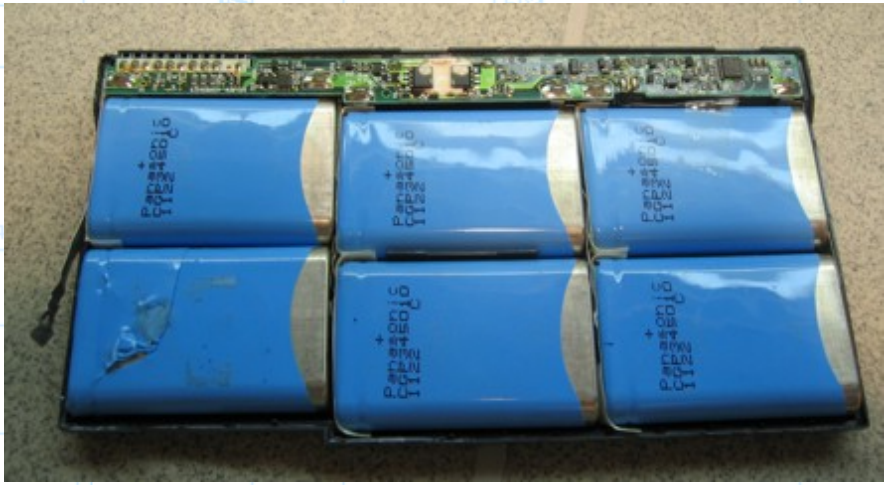
It is strongly recommended not to proceed to the following operations if you are not sure what are you doing or you have not fully understand the precautions previously talked about. Continue reading with your own risk. We advice you to work in a fire safe place and take all the necessary fire safety measures.

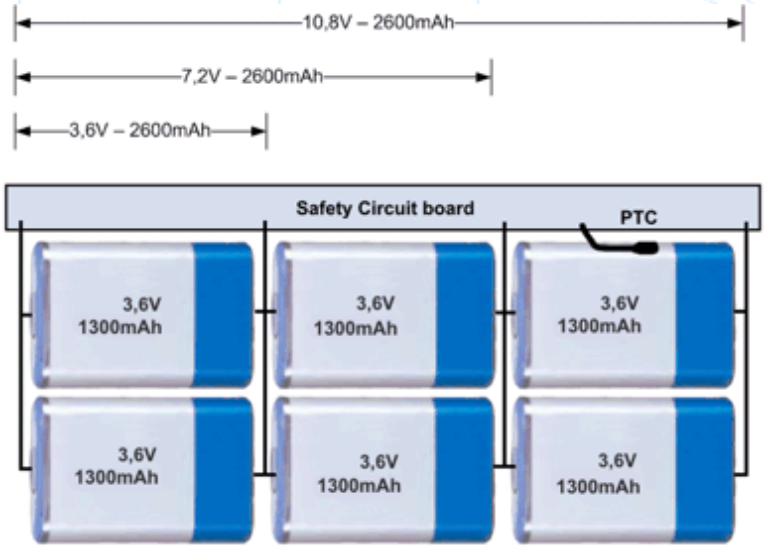
Disassemble

The pack is sealed to make it's disassemble hard. The cover is glued so it may be hard to remove it.

Take a screwdriver and put it in the split between the two covers of the battery pack, that's beside the cover. Try to turn the screwdriver and unglue a small side.

You may need to apply enough force to achieve this. Continue this operation to the entire pack. That's not too difficult, but for sure you will scratch the plastic. After some minutes you are victorious!





Now you have a clear view of the interior. You see that the pack comprises from 6 Li-Ion cells and a circuit board that contains all the safety circuits.

After a more detailed examination you will find that the batteries and connected in three series of two batteries each one. Look at the following image to understand the actual structure.

As you see the expected characteristics of each cell, according to the connection and the entire pack characteristics, are 3,6V and 1300mAh capacity.

Identifying the cells

On top of each cell is a part number **CGP345010** (click for the datasheet) that's a Panasonic's Li-Ion prismatic cell. As you can see in the datasheet this cell has a nominal voltage 3,7V and 1400mAh.

That's above the expected value of each cell as calculated according to the battery pack characteristics, but the part number of each cell are identical (and both manufactured by Panasonic). So what's is happening?

The most possible explanation is that Fujitsu has rated it's battery pack a little bit lower than the actual nominal ratings for a reason. The cell are for sure the same.

Find the cells

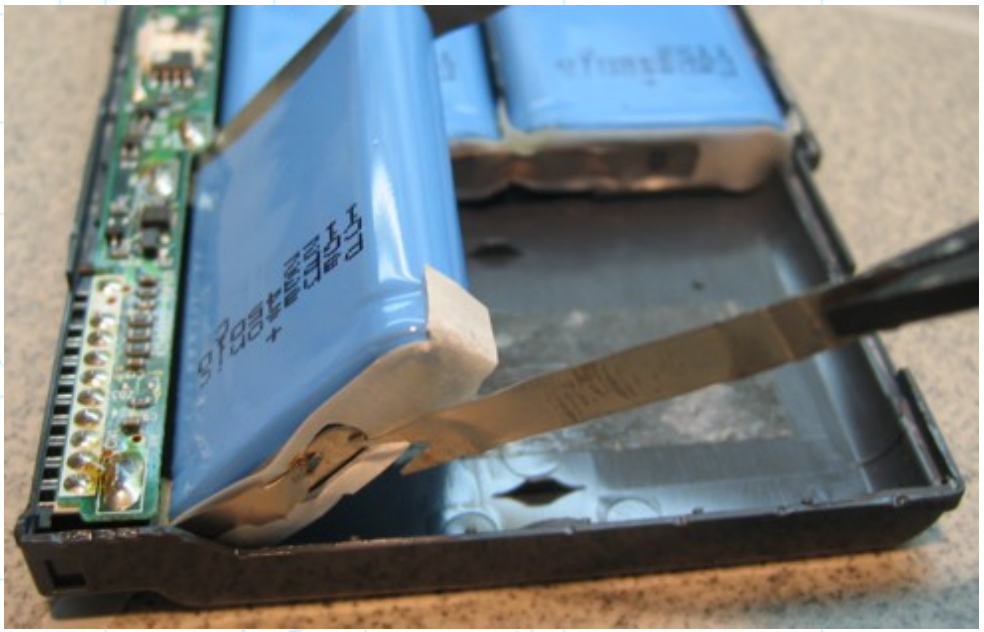
Now we have identified the cells that comprises the pack it's time to check if we can find them in market. Now you need to be lucky.

We found the cells on **www.AllElectronics.com** at a reasonable price. That's exactly the cells we need with an additional protection circuit that we don't need and we are going to remove it

Take the battery out

With the help of a screwdriver lift the first battery and cut the first connector as seen on the left photo.

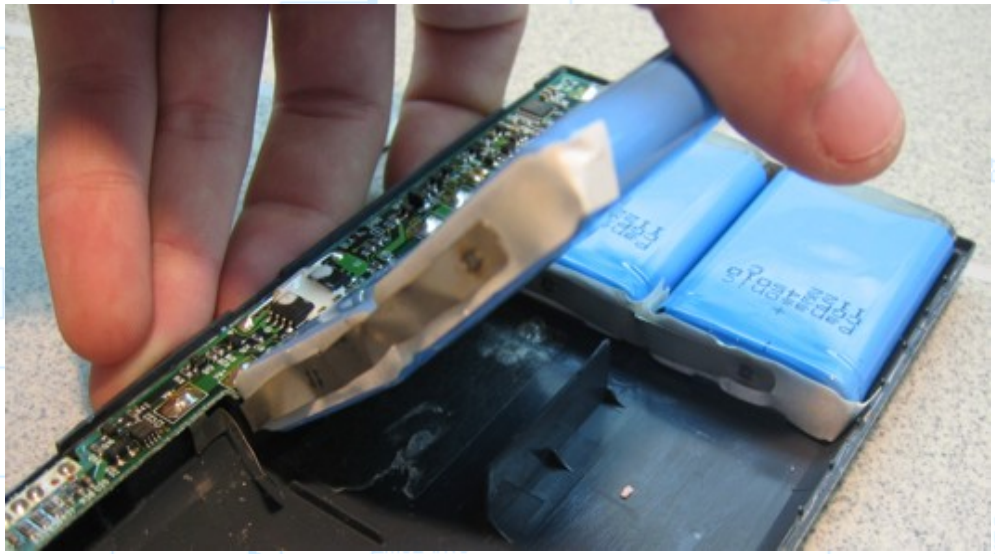
Lift carefully the second cell trying not to damage the circuit board.



With the help of a cutter, cut the remaining metallic contact and keep it as you will need it later.

Now cut the other side of the contact that goes to the pcb.

Continue cutting the other edge of the contact.

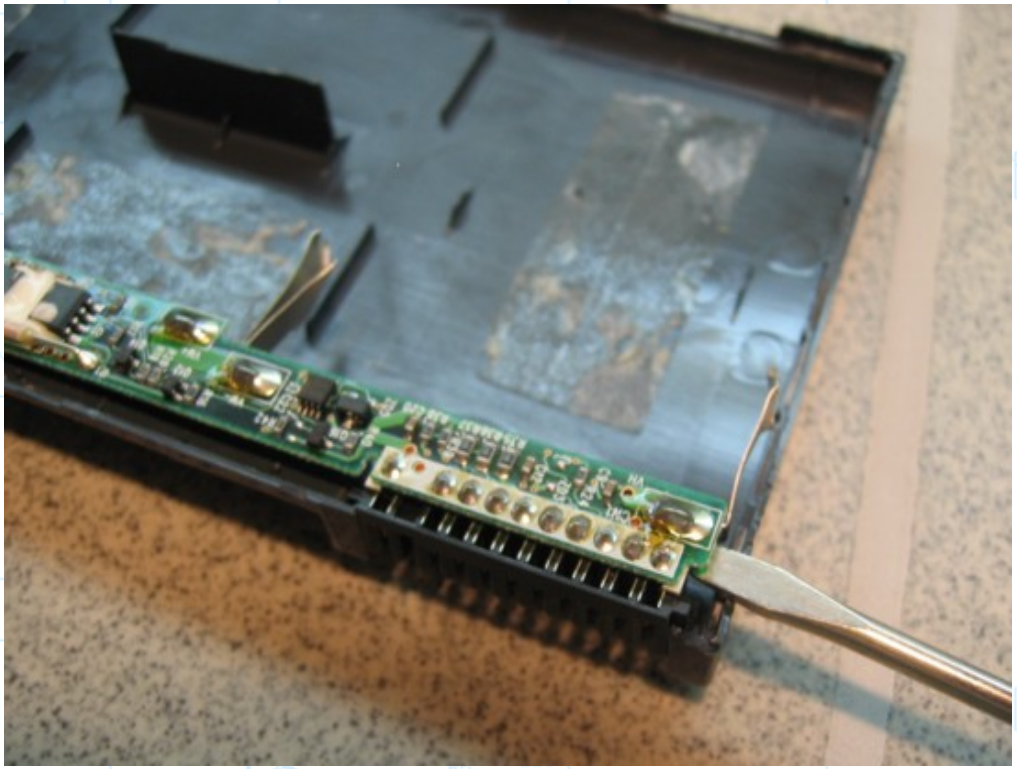


Continue removing the next cells in series.

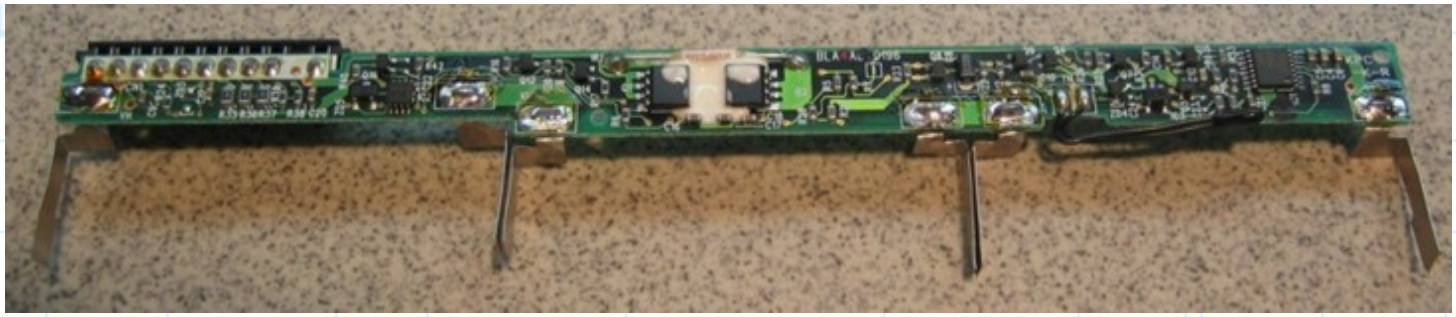
In the final cell you must pay more attention because there is a PTC attached on top of it.

Carefully remove the adhesive tape and free it from the cell. Now you can also remove this cell.

Place all cells in a distance so there is no chance to short circuit them. Don't throw away old ones as you will need them later.



Finally remove carefully the safety circuit board without damaging it, as we will use it again!



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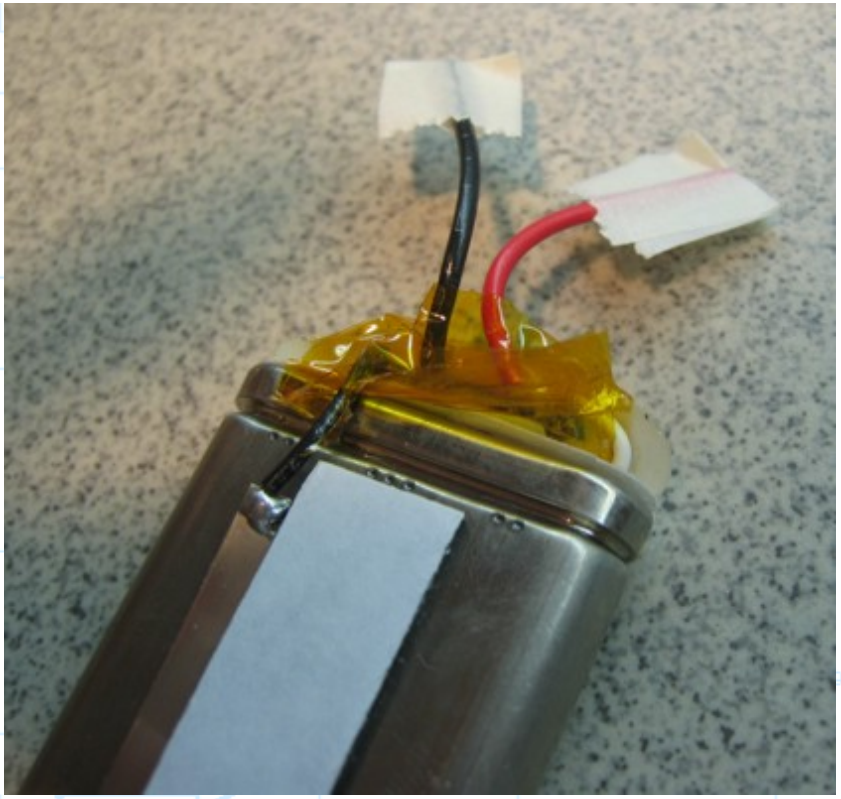
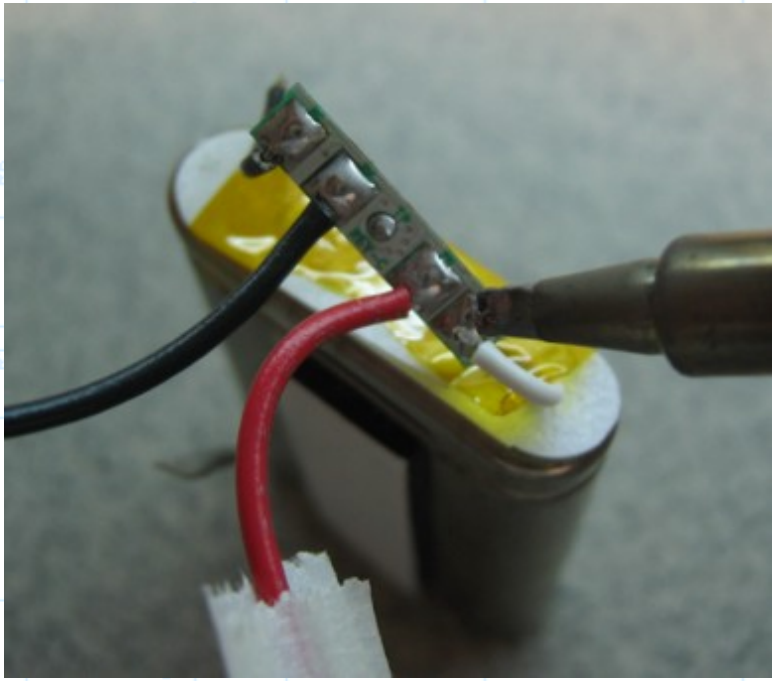


Take a new cell. As you see there is a small circuit board connected on top of the battery under the orange tape.

Start heating your soldering iron

Remove the orange tape to free the board.



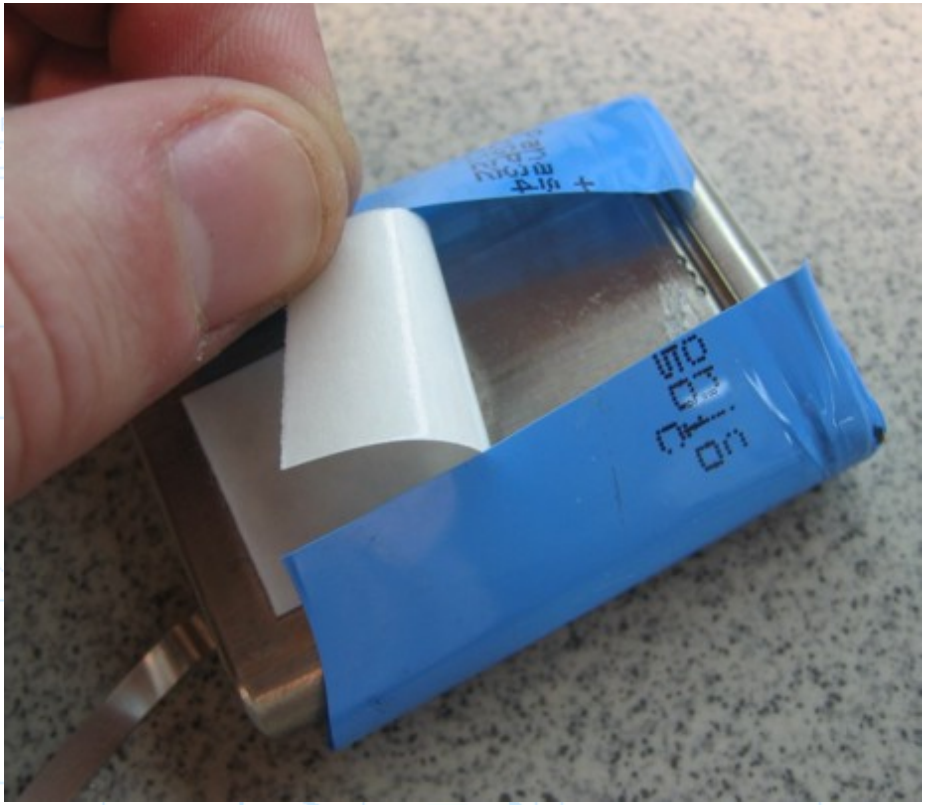
Desolder both contacts of the leads that are attached to the battery cell.

Now you battery should look like this. Remove the white cable but don't remove the white coating that protects the battery terminals from short circuit.

Remove the double sided adhesive tape as it's too thick and needs to be removed so battery fits back to it's place.

Now take the old batteries and remove the top white coating

and the blue heat shrinkable plastic as we are going to use it to the new batteries.



Now place the blue plastic on a new battery so the cut side faces the thin adhesive tape that we haven't removed.

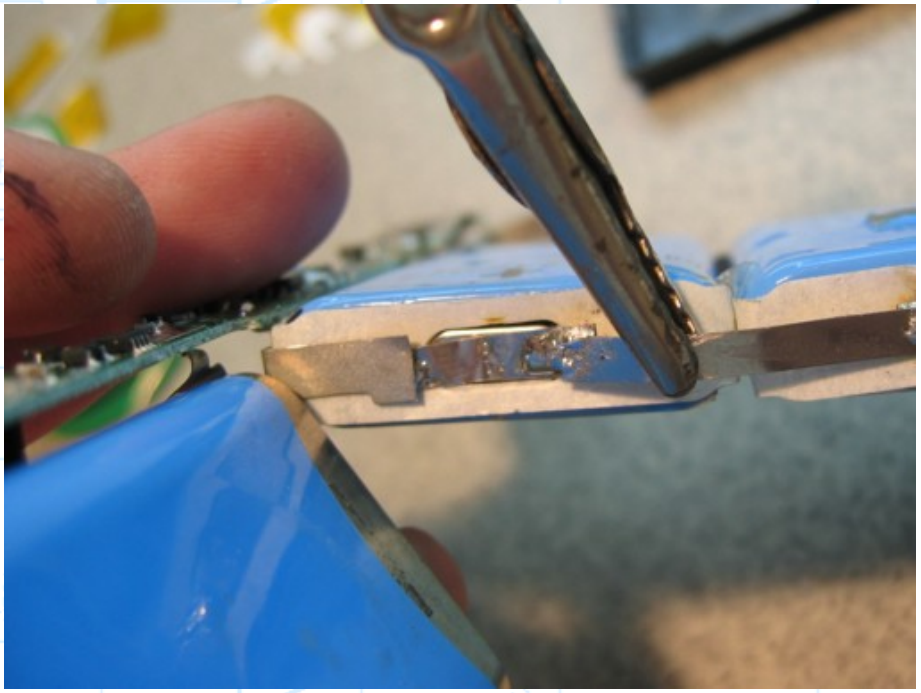
Press the plastic to glue on top of the tape

Next attach the white protective coating you have removed from the old batteries.

Repeat all the steps for all the

batteries. Now you must have six ready to solder batteries.

Solder the batteries in series of two. As on the diagram in page one. Repeat this step to make three sets of two batteries in series.



Now solder the sets on the circuit board paying attention to the polarity.

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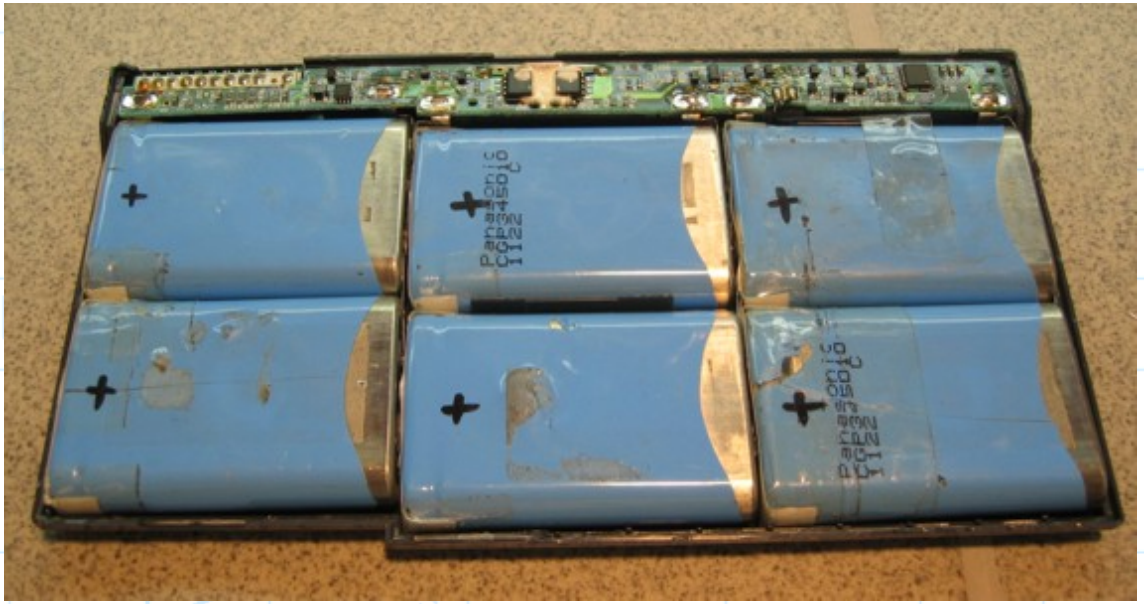
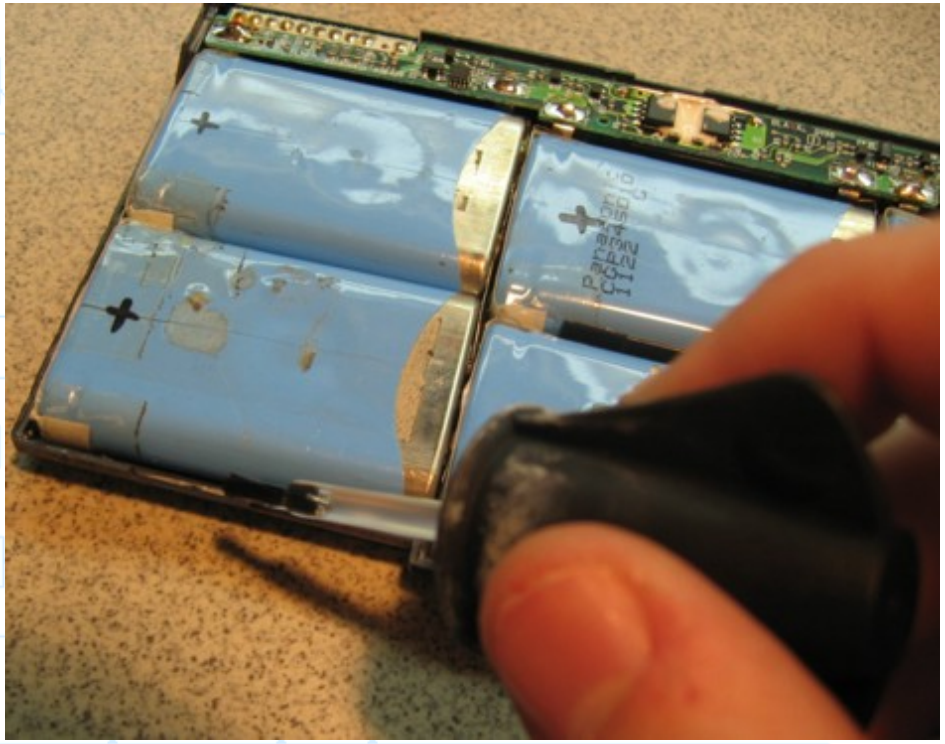


Place the pcb with the batteries soldered in the original plastic box. You should have try if they fit the box in your steps while soldering.

Use a multimeter to check for short

circuits. Measuring the cells you will see that are not fully discharged it's recommended to store Li-Ion cells in a 40-50% charge level.



If everything looks good, apply some glue around the plastic case.

You can also use clamps to glue the plastic encloser tautly

As long as the glue takes to dry

place the old cell on a separate small plastic bag and depose to a battery recycling bucket. Don't throw them along with ordinary rubbish.

Now it's the big time! Place the pack back in your notebook. If everything is ok the indicator should saw that the battery is charging normally. The arrow in the above image shows this.

The first charge took around 2.30 hours to complete and the first discharge last about 2.45 hours. That's good results! Now your notebook looks like new!

During the first 3-4 charges cycles don't let the notebook charge in another room that this you are so you can observe for any malfunctions that can cause excess heat during charging - discharging.

.: Resources

Download the article in PDF format (1,6MB)

References about Panasonic CGP345010 Cell

- Panasonic rechargeable lithium ion battery OEM products
- Online Li-Ion cells at AllElectronics.com
- CGP345010 3,7V-1400mAh Panasonic Prismatic Cell - Datasheet
- Li-Ion rechargable Cell Thermal-Vacuum Test Results
- An Innovative Low-Cost Communication Sattelite using CGP345010 cells (PDF)
- Nanosatellite Final Design Report

Li-Ion Charger Application Notes

- Charging Simplified for High Capacity Batteries - Microchip application note
- A Li-Ion battery charger using TSM102A - ST Microelectronics
- Highly Integrated Single-Cell Li-ion/Li-Polymer battery charger - Intersil
- Off-line Li-Ion battery charger with P89LPC916 - Philips
- LM3647 Reference Design User's Manual - National
- How to Design Battery Charger Applications that Require External Microcontrollers - MAX846A

Other Sites

- http://www.surfbaud.co.uk
- Power ICs Charge Ahead In One-Cell Li-Ion Applications
- More Li-Ion Charger ICs

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